Architectural Assessment for Optical Networks Deployed on Commercial Avionic Communication Systems

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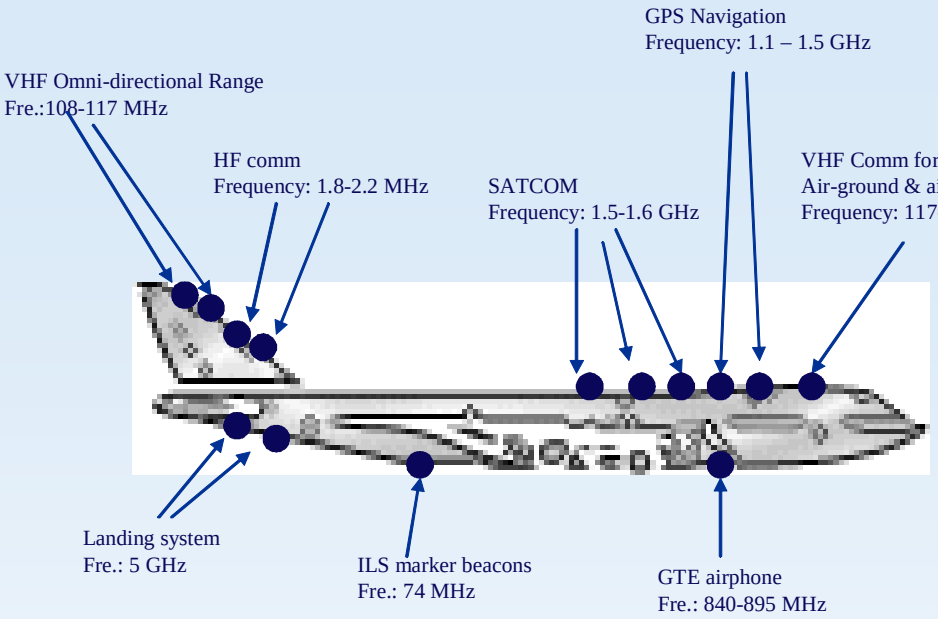
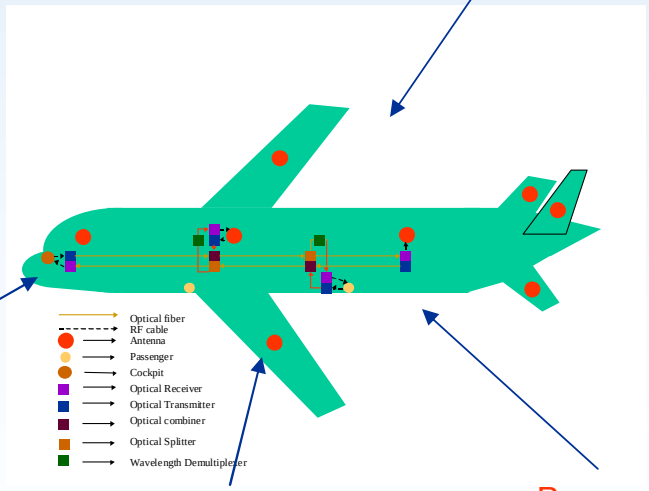


Broadcast satellite service providers

Simplified and light-weight optical networking system for radio frequency transmission



Phased-array antenna allowing simultaneous connections between satellites and ground stations

Source: NASA

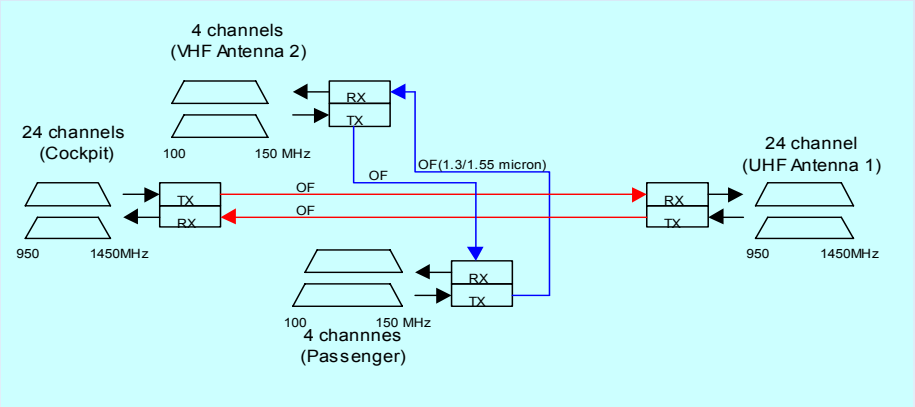
Passenger Data Services:

- Providing live television, Internet, HDTV, financial news, E-commerce, on-board checking status for connecting flights, etc.

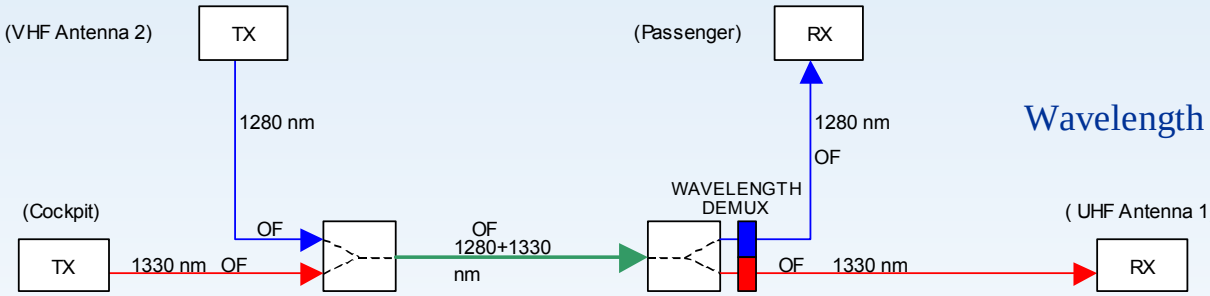
Existing Networking System	RF/Optical Networking System
Susceptible to Electromagnetic Interference	Immune to EMI No need of EMI back-shells
Increased volume of Cables/Wires	Single fiber for transmission-less space and reduced weight; greater bandwidth
Susceptible to Electrical Spark Influence	Network design flexibility and capacity
	Improved reliability, simplified maintenance
	Reduction in RF emissions from leaky coaxial cable

- Coaxial Cables for RF signal distribution
  - Low bandwidth
  - Lossy
- Interference
  - Low signal to noise ratio
- Weight
  - Coaxial cables add weight to the aircraft
- Inflexible to future applications
  - passengers can select video to view
  - Internet browsing

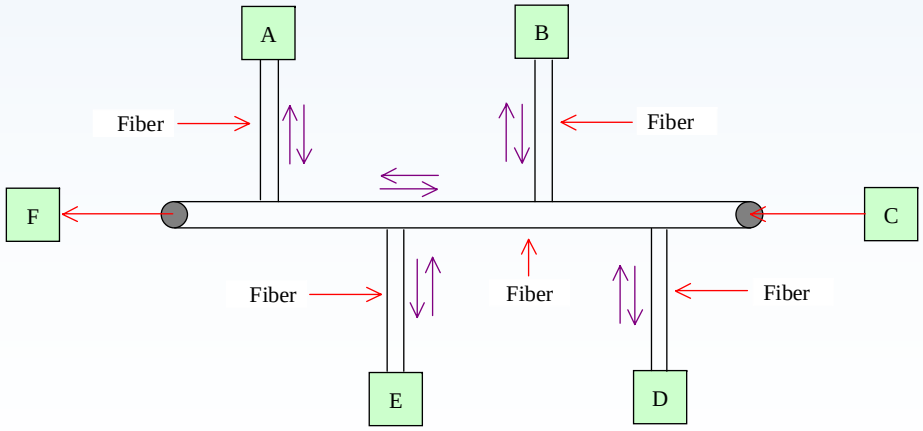
- No Electromagnetic interference, low transmission loss and electrical isolation (no spark hazard)
  - signal security
  - safer aircrafts
- Lightweight
  - suitable for aircraft
- Lots of bandwidth
  - Good for future applications
  - Voice, video, data can be carried over the same infrastructure



Point-to-Point Fiber Transmission

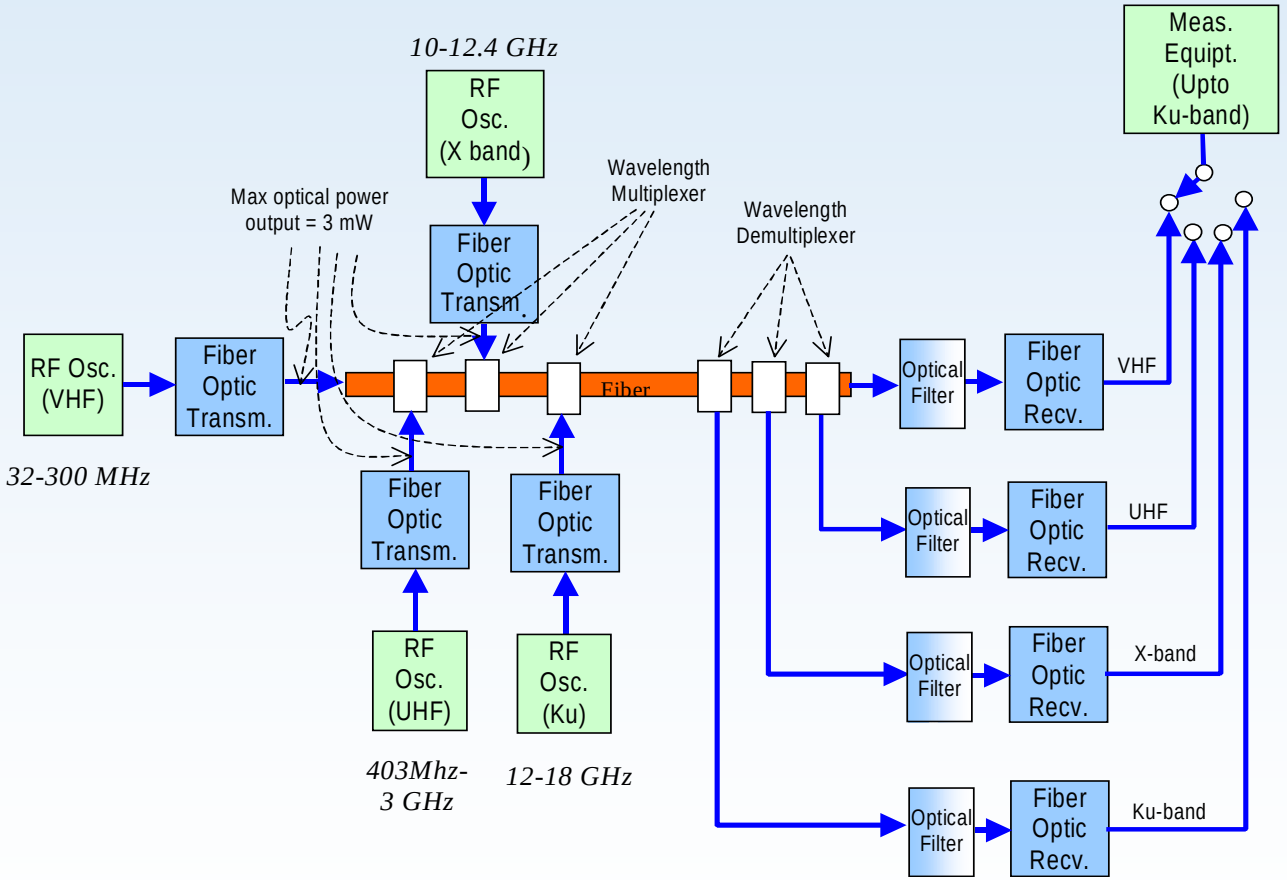


Wavelength Division Multiplexing



Bus-based Fiber Backbone using WDM

Four Different RF Frequency Band: VHF, UHF, X, and Ku



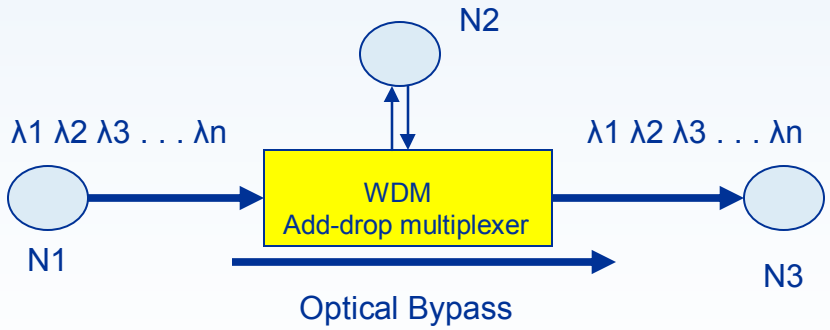
Optical Wavelength Division Multiplexing (WDM) Approach

Methods of multiplexing different network data into a single transport stream.

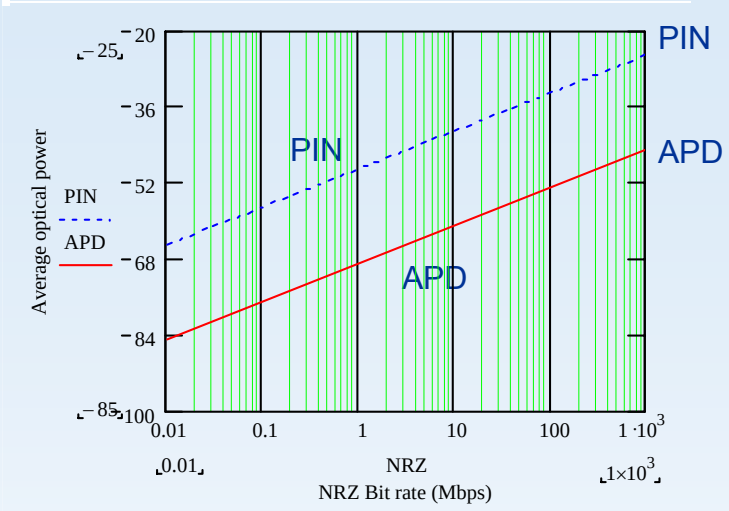
- SONET/SDH (Synchronous digital hierarchy) time division multiplexing system
- Ethernet system
- ATM (Asynchronous transfer mode) " packaging based or cell" multiplexing system

WDM system

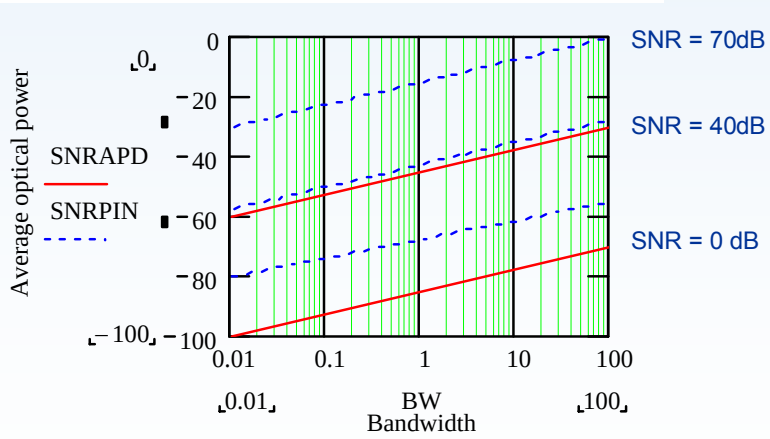
- Different wavelengths support different "electrical" multiplexing services.
  - A number of wavelengths dedicated to a high bandwidth optical IO network.
  - Others dedicated to optical ATM networks.
  - Some dedicated to SONET / SDH networks.



Requirement of analog and digital system

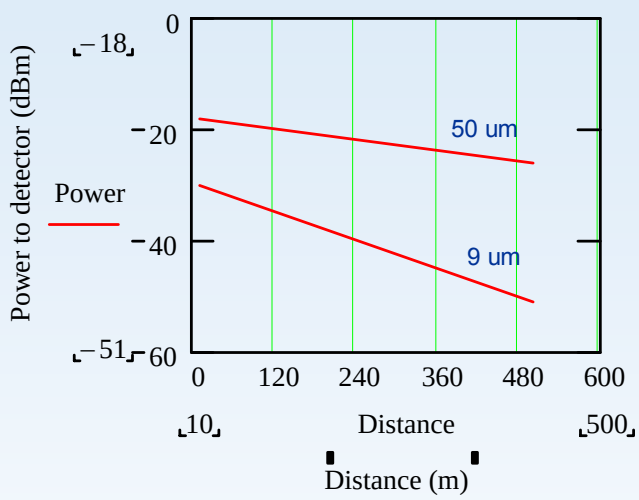


Digital signal (BER= 10^{-9})

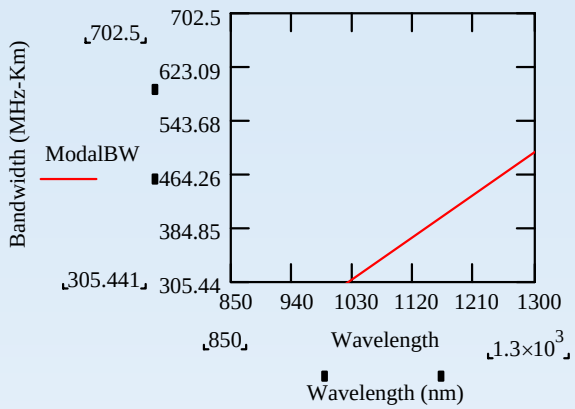


Analog signal

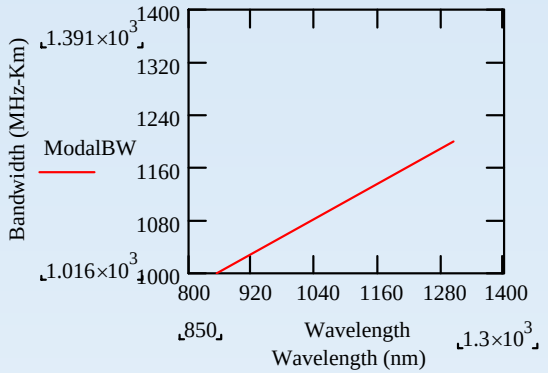
PIN: PIN photodiode (no gain)
APD: Avalanche photodiode (internal gain)



Fiber distance compared for two fiber's size: 50 and 9 um at 1330 nm wavelength and 500 Mbps.



Modal Bandwidth for multimode fiber (50 um)



Modal Bandwidth for single mode fiber (9 um)

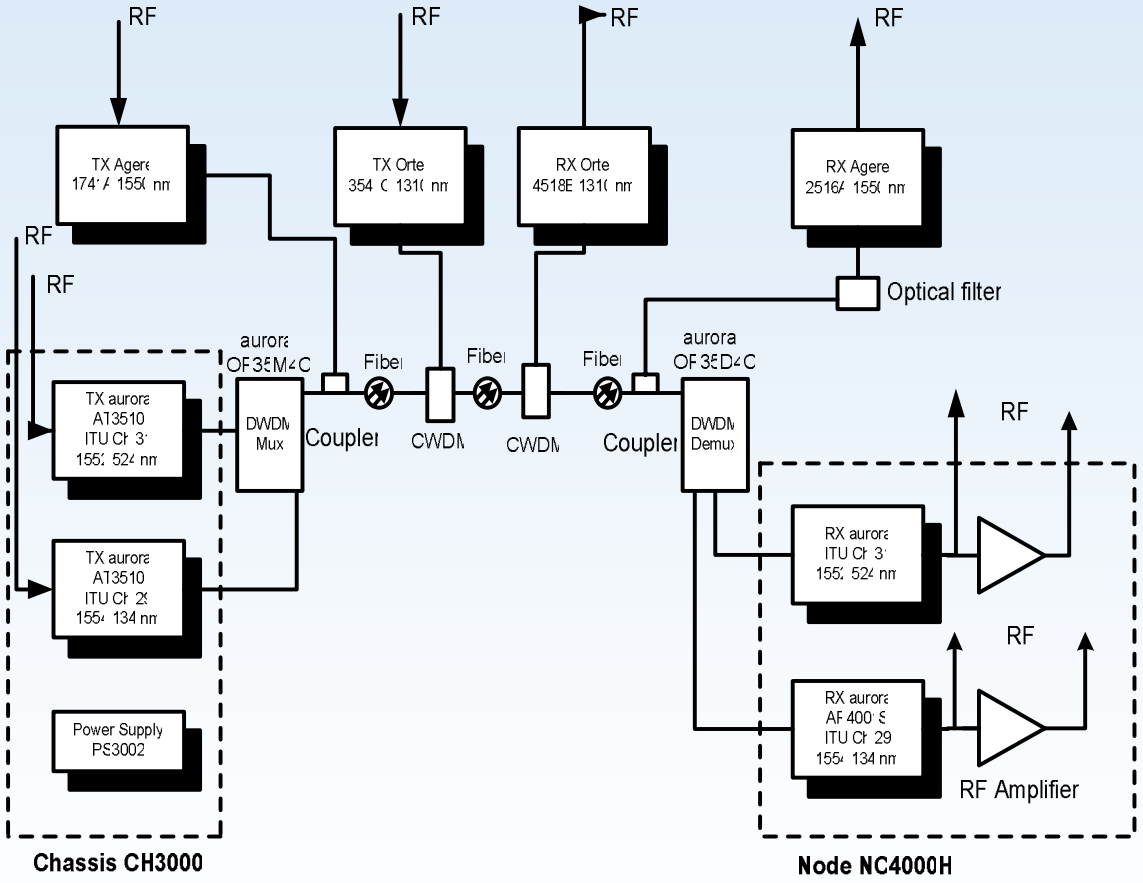
Cable Loss and Weight assessment for electronic networking backbone system.

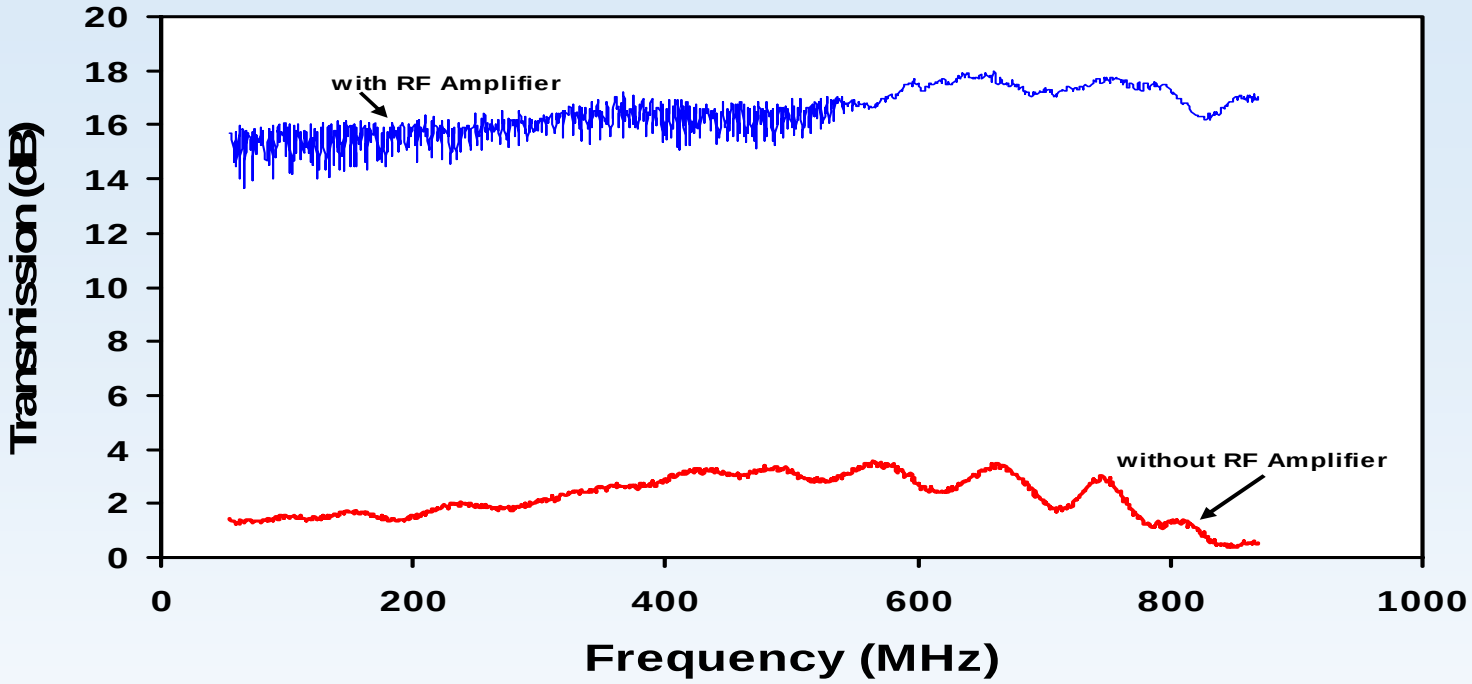
Distance from antenna to cockpit (ft)	Frequency	Loss (dB)	Weigh t (lb)	Total weight (lb) @ 4 Cables
100	VHF	5.9	1.3	5.2
150	VHF	8.85	1.95	7.8
200	UHF	11.4	30	120
300	UHF	17.1	45	180
100	VHF	5.9	1.3	5.2
200	UHF	11.4	30	120
300	UHF	17.1	45	180
		77.65 dB		618.2 lb

Fiber loss and Weight for RF/Optical networking backbone system

Frequency	Loss (dB)	Weight (lb)	Total weight (lb) @ 4 fiber Cables
VHF	.1 dB / 600 ft	5.4 lb /600 ft	21 lb
VHF			
UHF			
UHF			
VHF			
UHF			
UHF			
	.1 dB		21lb

WDM Architecture System Experimental Setup

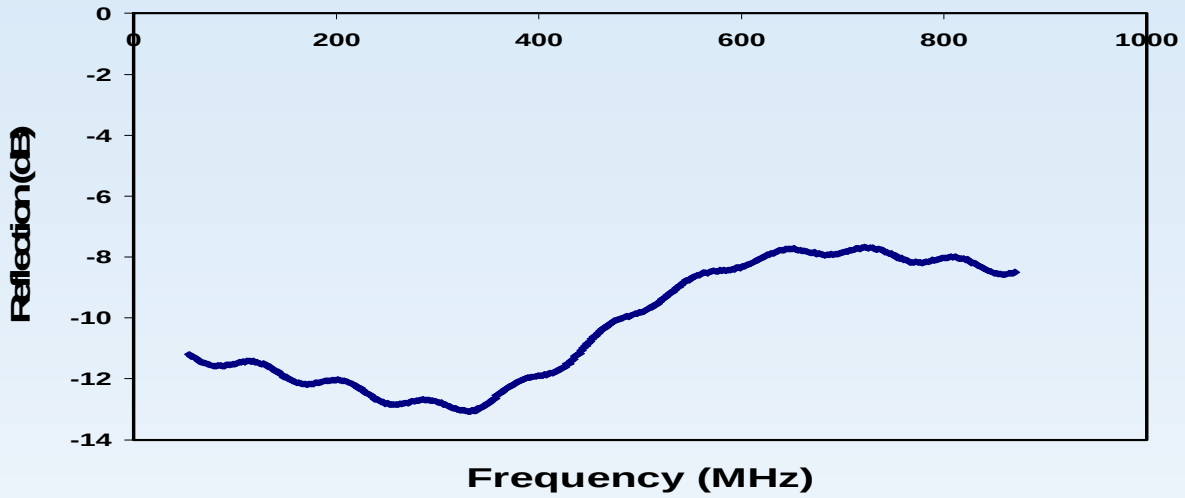




- Direct modulation
  Wavelength:1554.134 nm
  RF input: 46-870 MHz
  Optical output

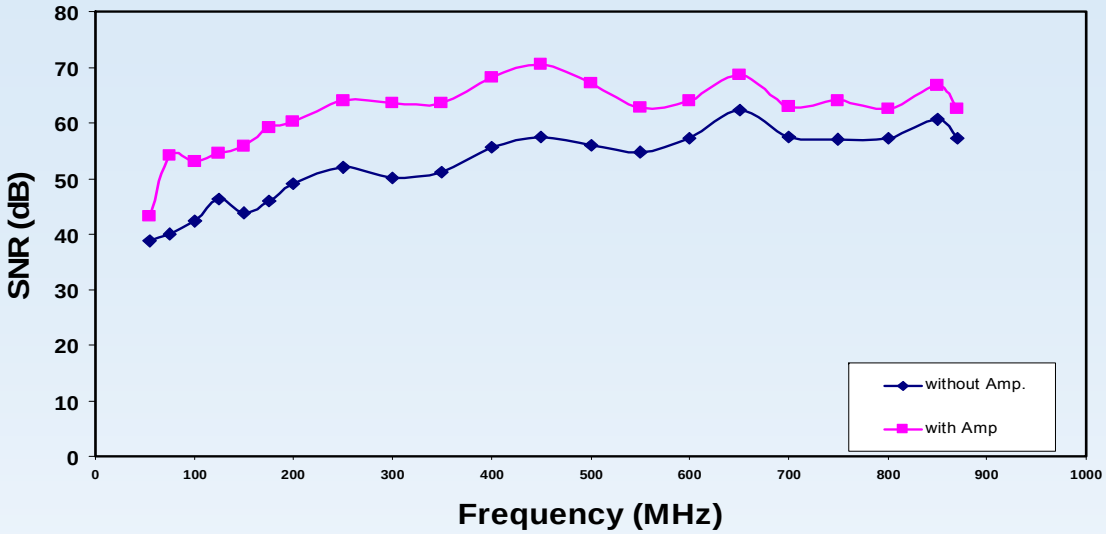
$$Transmission(dB) = 10\log\left(\frac{P_{trans}}{P_{inc}}\right)$$

- Transmission response without the RF amplifier varied around 2dB over the frequency range of 55-900 MHz.
- Transmission response with the RF amplifier varied around 16 dB over the same frequency range.

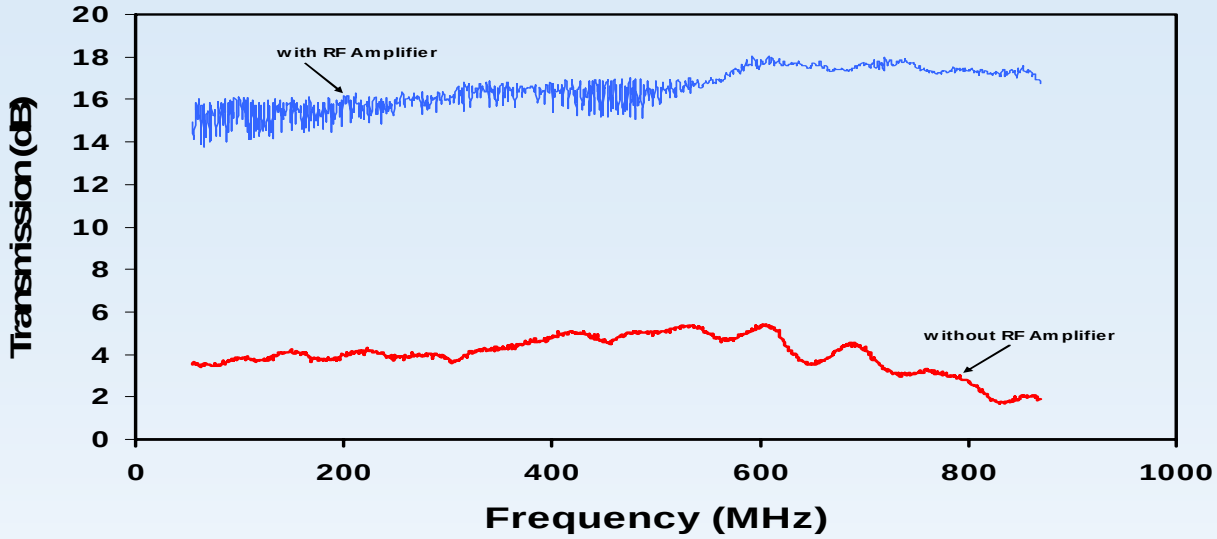


- Reflected power is due to the impedance mismatch between the RF input cable and the transmitter.
- Also, reflected power can be due to the transmitter laser modulation circuitry.
- Reflection response for channel 29 varied around -10 dB over the frequency range 55-900 MHz.

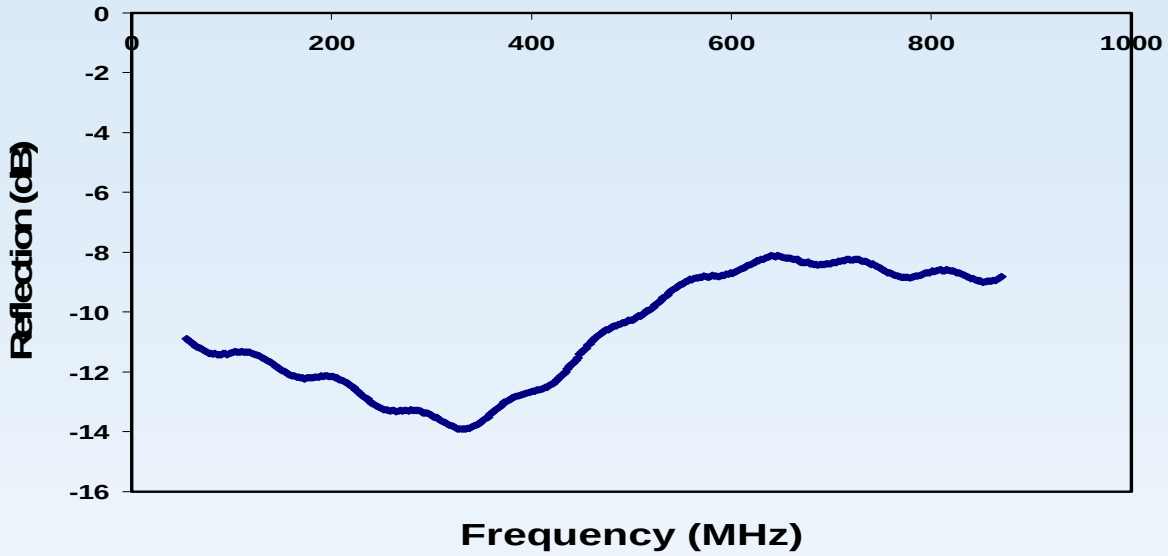
$$Reflection(dB) = 10\log\left(\frac{P_{refl}}{P_{inc}}\right)$$



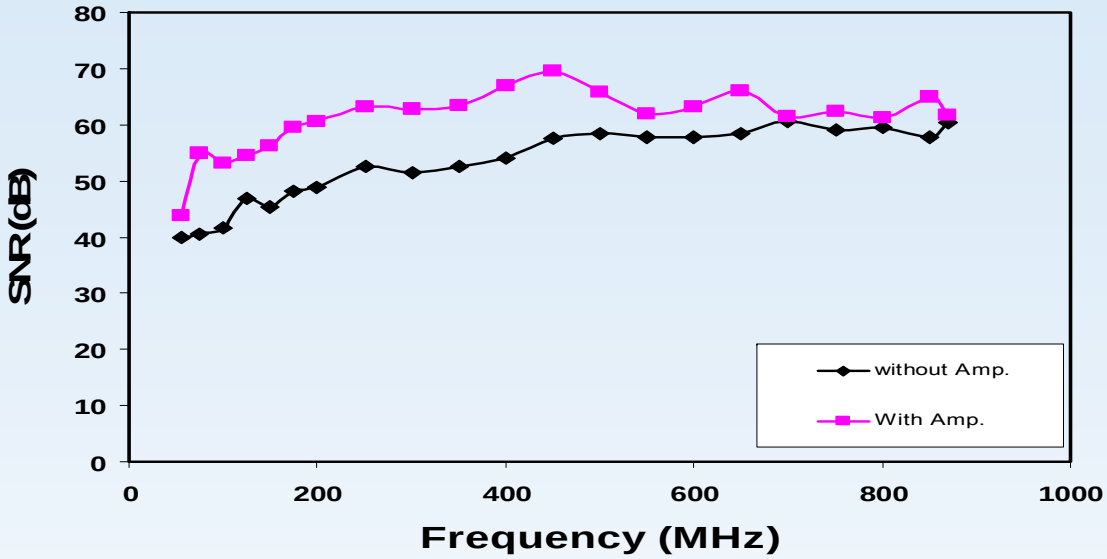
- SNR without the RF amplifier varied between 38.77 dB and 60.69 dB over the frequency range 55-900 MHz.
- SNR with the RF amplifier varied between 43 dB and 68.69 dB over the same frequency range.



- Direct modulation
  Wavelength:1552.524 nm
  RF input: 46-870 MHz
  Optical output
- Transmission response without the RF amplifier is approximately 4 dB over the frequency range 55-900 MHz
- Transmission response with the RF amplifier is approximately 16 dB over the same frequency range.

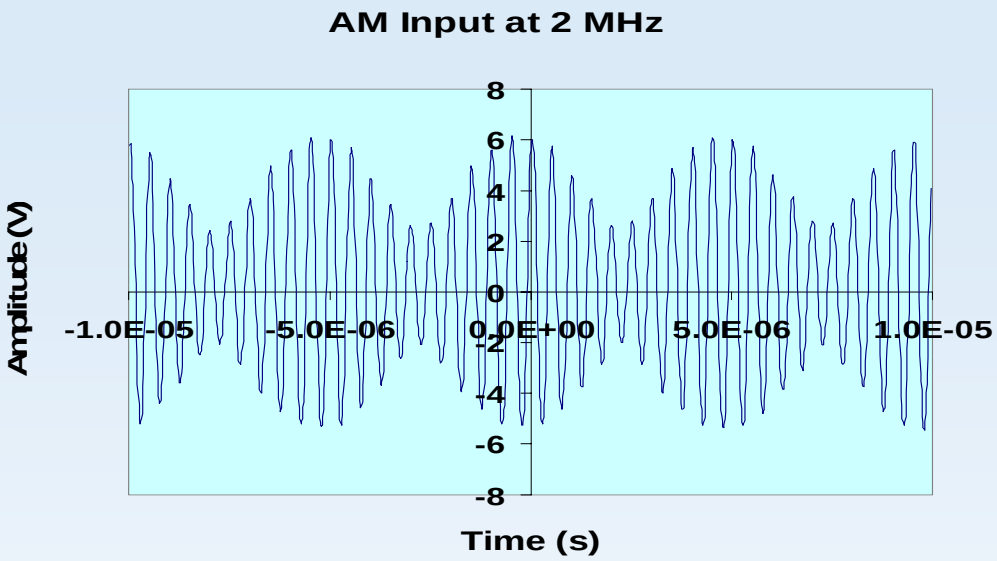


Reflection response for channel 31 is varied between -8.16 dB to -13.91 dB over the frequency range 55-900 MHz.

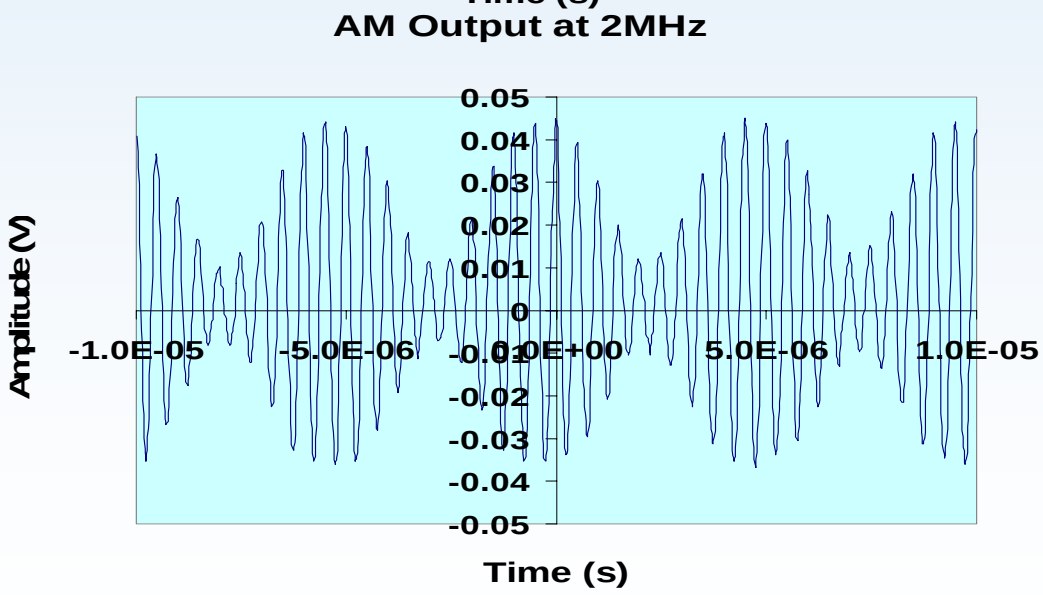


- SNR without the RF amplifier varied between 39.81dB and 60.53 dB over the frequency range 55-900 MHz.
- SNR with the RF amplifier varied between 43.71 dB and 69.51 dB over the same frequency range.

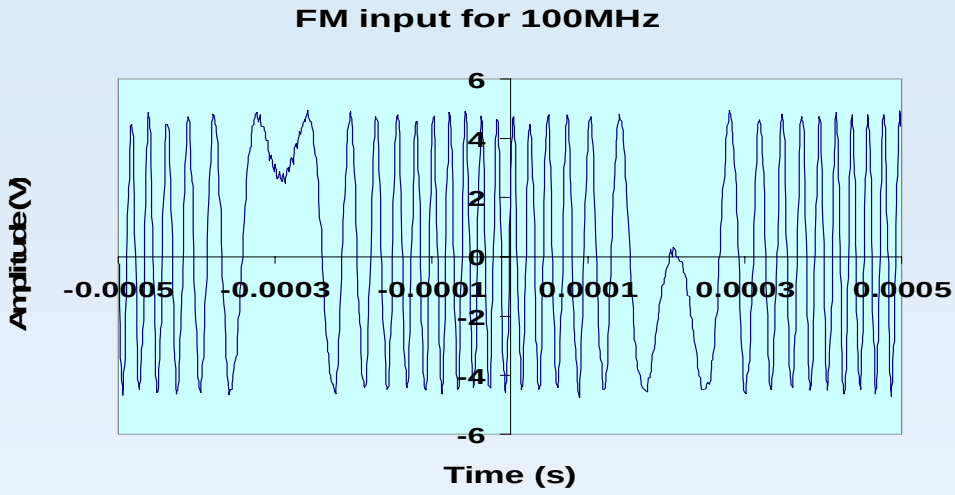
- AM modulation
  - Carrier: 2 MHz
  - Modulating signal: 200 KHz
  - Modulation Index:30%



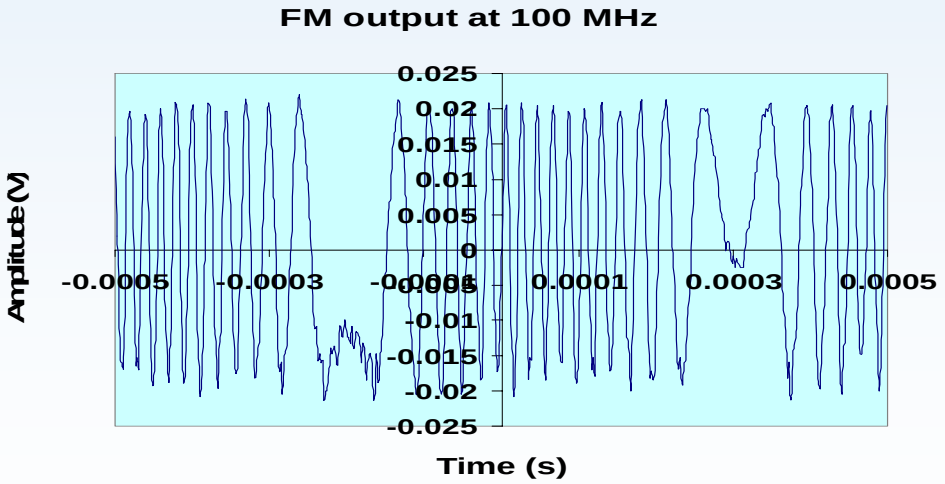
- High signal quality of the AM signal is preserved in the output waveform.
- Output shows very little distortion, which is numerically measured and presented in the Distortion Test



- FM modulation
  - Carrier: 100 MHz
  - Modulating signal: 1000 Hz
  - Deviation:20 KHz

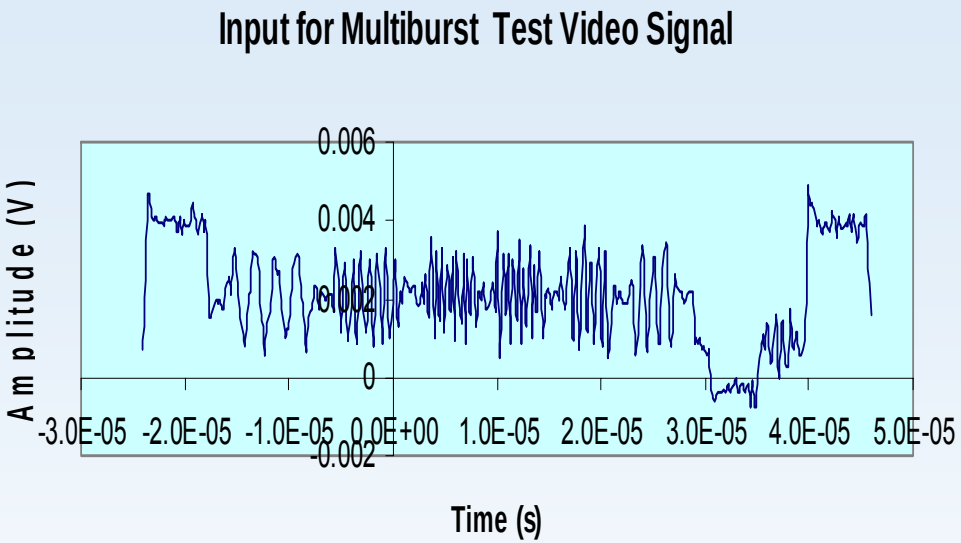


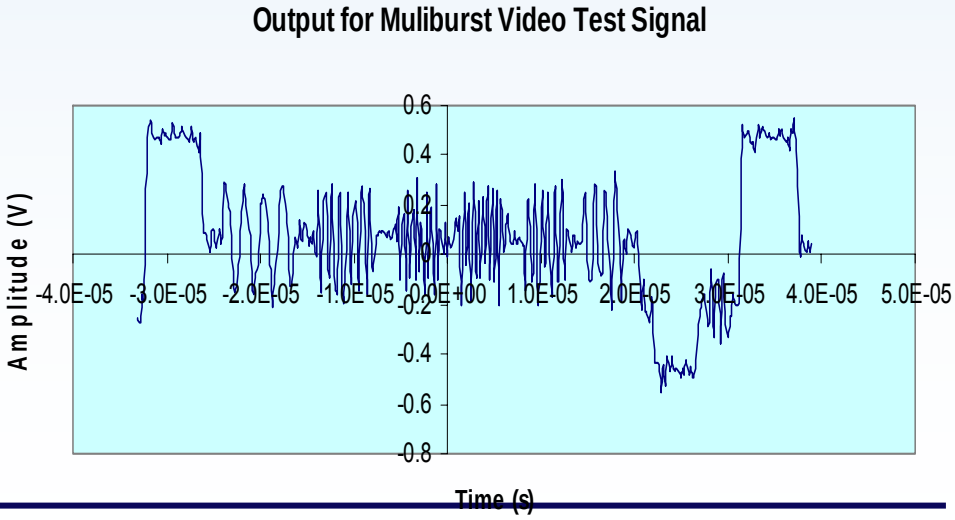
- High signal quality of the FM signal is preserved in the output waveform.
- Output shows very little distortion, which is numerically measured and presented in the Distortion Test



Input and Output Waveform Comparison

- Almost no distortion in the output
- waveform





Cross correlation of the input and output xcorr=.9984

Video Quality Input/Output Comparison

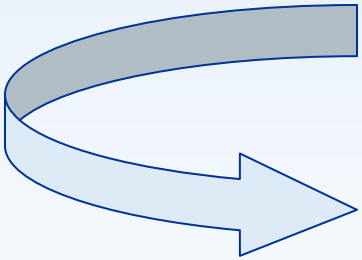
Input

Output

- **Camera snapshot input and output show identical quality**
- **No distortion in the output picture**

- No Electromagnetic interference, low transmission loss and electrical isolation (no spark hazard)
  - signal security
  - safer aircrafts
- Lightweight
  - suitable for aircraft
- Lots of bandwidth
  - Good for future applications
  - Voice, video, data can be carried over the same infrastructure

Cost slightly up



Optical Components	Cost
Protocol Converter	20 units x $520
Transceiver	20 units x $200
Add/Drop	10 units x $400
Fiber cable	600 ft x $3
	Total: $20,200

Cost assessment of RF/Optical Networking backbone components.

Thank You for Your Attention